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MELBOURNE, VICTORIA

Aircraft Systems Technical Memorandum 149

FLIGHT MOTION PREDICTIONS FOR THE JINDIVIK/HAYES TPT-5A TOWED AERIAL TARGET SYSTEM

by

D. CHARLTON

Approved for public release

DECEMBER 1991

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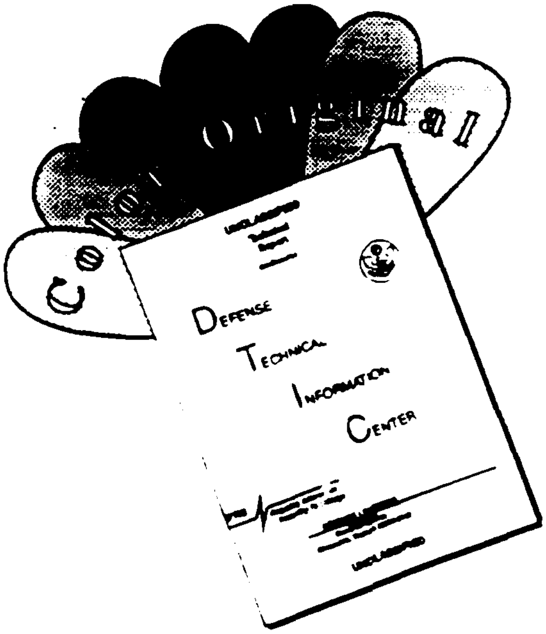

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FLIGHT MOTION PREDICTIONS FOR THE JINDIVIK/HAYES TPT-5A TOWED AERIAL TARGET SYSTEM

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SUMMARY

The UK sourced CBAS computer model, with some enhancements implemented by the Aeronautical Research Laboratory, is being used to investigate the potential for Jindivik induced manoeuvres to provide transient response of the Hayes TPT-5A target to improve presentation realism for AAM exercises, both from a hardware and human operator point of view. This Memorandum examines the Jindivik performing a constant-altitude semi-circular banked turn, for different tow cable length/airspeed/angle-of-bank combinations and predicts target trajectories, accelerations, and tow cable tensions. However, as the model is unvalidated the results must be treated with caution.

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Victoria Australia

CONTENTS

1. INTRODUCTION

Aeronautical Research Laboratory (ARL) via a RAAF sponsored task is investigating means of improving the presentation realism of the Jindivik/Hayes towed aerial target system (see Figure 1) currently employed in Air-to-Air Missile (AAM) firing exercises. Current practice involves straight and level presentations of the target system.

The UK sourced CBAS (Cable-Body Aerodynamic Simulation) computer model with some locally performed enhancements is being used to investigate the potential for tow aircraft (Jindivik) induced manoeuvres to provide transient response of the towed body (Hayes target). This will extend the training value of the AAM exercises, both from a hardware and human operator point of view.

This report provides an example of this simulation work viz examination of the Jindivik performing a constant-altitude semi-circular banked turn, for different tow cable length/airspeed/angle-of-bank combinations. The information contained was presented at the RAAF working group meeting on aerial towed targets held at DSTO-Salisbury in March 1991 [see Reference 1].

2. JINDIVIK - HAYES COMBINATION

2.1 Flight Cases

2.1.1 INITIAL FLIGHT CASES - Table 1 (below) gives the set of flight cases suggested in Reference 2. For brevity, eight (two cable lengths, by two airspeeds, by two bank angles) of the possible 48 flight cases were modelled (see highlighted cases in Table 1).

A further case was added later upon request , as noted in Section 2.1.2.

Table 1 - Flight Cases

CONDITION	CABLE LENGTH (ft)	AIRSPEED (KIAS)	AOB (deg)
1	**2000**	**200 [106]**	**40**
2	5000	250	50
3	**8000**	300	**60**
4	11000	**350 [185]**	--

note 1 KIAS= Knots Indicated AirSpeed.

note 2 Airspeed values in [...] are calculated estimates (refer Appendix A) of equivalent airspeed (in m/s), for the Jindivik flying at an indicated altitude of 2000 feet above sea level. For the CBAS model equivalent airspeed is most conveniently used in conjunction with sea level air density for a standard atmosphere [1.225 kg/m^3].

note 3 Notation of the Flight Cases is a three digit system referring to the "condition" of the cable, airspeed and angle-of-bank (AOB) respectively. For example, Flight Case 141 refers to cable 1 (2000 ft), airspeed 4 (185 m/s) and AOB 1 (40 degrees maximum).

2.1.2 ADDITIONAL FLIGHT CASES - AeroSpace Technologies of Australia (ASTA) requested that one additional case be modelled. This has been called flight case **152**, representing 2000 ft cable, 430 KIAS (at 2000 ft) towing speed, and 50 degrees maximum bank angle.

2.2 Tow cable information

The Hayes TPT-5A (IR) target as deployed from the Jindivik has an internal tow-reel, pre-wound with the appropriate length and type of cable. The cable is mono-filament steel of either constant or stepped diameter, again depending on the particular mission to be flown.

Acquiring cable data has proved very difficult, with apparently all cables being supplied pre-wound and packaged from the overseas supplier. Difficulty has also been encountered in acquiring specific aerodynamic drag data for thin cables. Both of these problems need to be addressed to improve confidence in input data used for the model, and hence in the predictions. Appendix B gives details of the data used.

2.3 Hayes TPT-5A target information

CBAS requires a detailed set of mechanical and aerodynamic parameters to describe the towed body (Hayes TPT-5A target in this case, see Figure 2).

The mechanical and aerodynamic properties of the Hayes TPT-5A were directly calculated or estimated (as appropriate) from measurements taken directly from a target. References 3 and 4 were used in estimating the aerodynamic coefficients.

The aerodynamic parameter values used in this modelling (refer Appendix C) must be regarded as "first estimates" due to the approximations required in their theoretical calculation. To improve confidence in the values used, it is recommended that full/part scale target windtunnel tests be carried out to provide empirical comparisons of static derivatives at least.

3. DESCRIPTION OF SIMULATION MODEL

The CBAS theory and computer code was developed at Bath University, (UK) circa 1984-87, for analysing the behaviour of aerial towed systems. Initially this programme was written as CBUS (Cable-Body Underwater Simulator), then modified for the aerodynamic case.

CBAS represents the following ...

(a) Towing aircraft - described in terms of equivalent airspeed and flight trajectory (see Figure 3 for reference axis system). The towing aircraft is not considered to be influenced by the presence of the cable/towed body system. This is assumed to be valid for a total towed system mass not exceeding approx 1/50th of the towing aircraft mass. However, it should be noted that for the simulation described here the (Hayes TPT-5A and cable)/Jindivik mass ratio is approximately 1/20. A rigorous assessment of the significance of this breach of the assumed conditions has not yet been made, so the predicted results must be treated with caution.

(b) Tow cable - described as a discrete number of rigid, inextensible, freely hinged rod elements of constant diameter. Increasing curvature of the cable at the towed body end is allowed for by decreasing element lengths. Tow cable tensions are calculated from the forces between the cable elements.

Obviously a number of approximations are being made to model a continuous, flexible stepped diameter cable which is the real cable in this case. The significance of these approximations can only be assessed by on-going investigation of the underlying theory and by on-going validation of the code.

(c) Towed body - described in terms of tow point location with respect to centre of mass, mass/inertial properties and aerodynamic coefficients. Aerodynamic forces and moments on the body are represented as cubic polynomials of the angles of incidence and sideslip. Hence non-linear effects can be included in the simulation. Forces due to rotary motion are represented by rotary derivatives.

CBAS is based on a Newton-Euler form of the equations of motion of the system. Using this method the interactions between the cable elements are explicitly calculated. References 5 and 6 can be consulted for detail of the underlying theory.

For this modelling work, minor modifications were made to the CBAS code to allow a more detailed description of the towing aircraft flight path (see References 7 and 8). The Jindivik towing aircraft manoeuvre is approximated by a bank angle time function as shown in Figure 4. This function is converted into a XYZ co-ordinate versus time file which is read by CBAS.

For this report the equations of the resulting motion are solved using step-by-step calculation and the results output to a file at a specified time interval. Specific output comprise XYZ co-ordinates for towing and towed vehicles, body orientation angles and body accelerations for the towed body, and tension at each end of the tow cable.

Appendices D through G of this report show CBAS predictions presented in graphical form. These are discussed in Section 4 below. However, it should be noted that the CBAS programme is as yet, for practical purposes, **unvalidated**, and as such the following results can only be treated as **predictions**.

4. DISCUSSION OF PREDICTED RESULTS

4.1 Manoeuvre plan views

Appendix D shows that the general **deviation** of the Hayes target from the Jindivik flight path is small (around 50-100 m) for most of the flight cases presented. However, this deviation increases when towing aircraft turn diameter is of similar magnitude to the length of cable used, so that the cable trys to "cut the corner". Flight cases 311 and 313 are good examples of this, with deviations from the towing aircraft flight path of 300-600 m respectively.

4.2 Manoeuvre side elevations

Appendix E shows the target trajectory from the side elevation. The towing aircraft (Jindivik) maintains a constant altitude throughout the manoeuvre, thus is at zero (reference) Z-coordinate on the plots. The vertical separation between towing (Jindivik) and towed (Hayes) bodies decreases as tow speed increases (ie. speed increase corresponds to generation of additional lift force in this case so that the target flies at a greater altitude).

This can be seen as the target initially falls in altitude as the towing aircraft initiates the turn and cable tension relaxes slightly, then rises as the target takes up the cable tension and regains speed in the latter part of the turn. The **variation** in vertical separation increases with cable length, and bank angle (which relates to the magnitude of "disturbance" to the towed body flight path), but decreases with increased tow speed (as inertial forces increase and make variations physically more difficult).

4.3 Tow cable tensions

Appendix F shows the variation of maximum (towing aircraft end) and minimum (towed body end) tensions for the cable, being the upper and lower lines respectively. The tension is greater at the towing aircraft end.

The trend for the shorter cable (2000 ft) is a gradual rise in tension as the towed body negotiates the turn and a fall in tension at the exit of the turn. For the 8000 ft cable, the tension (particularly at the towing aircraft end) relaxes as the towing aircraft initiates the turn while the towed body continues on its original path, then rises as the cable takes up the tension and forces the towed body to initiate the turn. Again, the **variation** in cable tension increases with cable length and angle-of-bank.

The predicted results appear reasonable and are much better behaved than those of Reference 9 which exhibited sizeable and rapid fluctuations. This improvement appears to be due to the better representation of transitions between straight-and-level flight and banked manoeuvres (Reference 9 representing these transitions as instantaneous steps), and better choice of number and length of cable elements. The latter of these are by far the most significant (based on ARL's experience with the code to date).

Note there is a "glitch" in the predicted results for maximum tension at the 71-second interval of simulation. This fault has not been traced to date but is not thought to be affecting the rest of the results.

4.4 Target absolute accelerations

Appendix G shows the predicted magnitude of absolute acceleration of the towed body throughout the manoeuvre. The towing aircraft maximum angle of bank [AOB] relates to its **lateral** acceleration (viz tangent[AOB]) and **normal** acceleration (1/cosine[AOB]) as shown in Table 2 below.

Table 2 - Accelerations corresponding to Towing Aircraft Bank Angle

BANK ANGLE (degrees)	LATERAL ACCELERATION (g)	NORMAL ACCELERATION (g)
40	0.84	1.31
50	1.19	1.56
60	1.73	2.00

In each case the towed body will respond to this input. For the short cable the results approximate a "classical" ramp response. The maximum values attained are close to the input value and so the predictions appear reasonable. For the longer cable the responses are much more "damped" (as any motions initiated by the towed body are unlikely to match natural mode frequencies of the tow cable), and likewise appear reasonable. Speed does not appear to have such a great effect on the overall results, but the time taken for the target to respond to towing aircraft manoeuvres decreases with increasing tow speed.

The results show that the Hayes TPT-5A is not achieving significantly greater acceleration than the Jindivik for any length of time. However medium level acceleration (1-1.5 g) appears achievable for varying lengths of time as indicated in Table 3 below.

Table 3 - Hayes TPT-5A absolute acceleration "bandwidths"

FLIGHT CASE	JINDIVIK LATERAL "g"	TIME (sec) FOR WHICH TPT-5A EXCEEDS... 1.0g	1.5g	2.0g
111	0.84	--	--	--
113	1.73	15	10	--
141	0.84	--	--	--
143	1.73	30	25	--
152	1.19	55	--	--
311	0.84	--	--	--
313	1.73	15	10	5
341	0.84	--	--	--
343	1.73	15	10	--

5. VALIDATION

Collection of a significant database of validation data is **essential** to the on-going development of the CBAS model. This will require support from the Australian Defence Forces (ADF). Collaborative effort via The Technical Cooperation Panel (TTCP) also has potential to redress the situation of inadequate validation data resource.

Tow cable instrumentation was trialed at the June 91 AAM firing exercises versus Jindivik/Hayes TPT-5A target at the Jervis Bay Range Facility (NSW). CBAS predictions were found to be in reasonable agreement with the (limited amount of) recorded data, as reported in Reference 10.

It is intended in future trials to include a means of trajectory tracking for towing and towed vehicles. This is likely to require support of a RAN FFG/DDG (having a dual "target" tracking facility), but independent land-based tracking systems are also under investigation.

NCDS (Naval Combat Data System) tapes from other aerial target exercises (eg. FFG shipboard 76 mm firing exercises versus Learjet/Hutts which would allow cable tension monitoring via the Marquardt reel recorder) also represent a source of validation data, and will be requested at future trials.

6. CONCLUSIONS

The predicted results indicate that the Hayes TPT-5A target follows the Jindivik's banked turn manoeuvre reasonably well for the flight cases modelled. Results predicted for cable tension, and target absolute acceleration also appear well-behaved.

Medium level target acceleration appears achievable and as such would provide a more realistic missile engagement than that provided by the previously employed straight-and-level presentations.

It should also be noted that for some cable length/tow speed/bank angle combinations, significant vertical displacements of the target occur throughout the manoeuvre (see Flight Case 313 for example). These cases correspond to the most dramatic cable tension variations and highest peak target accelerations. This behaviour might be employed to enhance the training value of such engagements.

However, as noted in Section 3 of this report, CBAS is **unvalidated** and as such its output can only be considered as a preliminary prediction. Further, confidence in parameter **values** used to describe the tow cable and Hayes TPT-5A target is only moderate. This confidence would be increased by conducting physical tests/measurements on hardware.

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DoD (Air Force Office) Canberra
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FIGURES

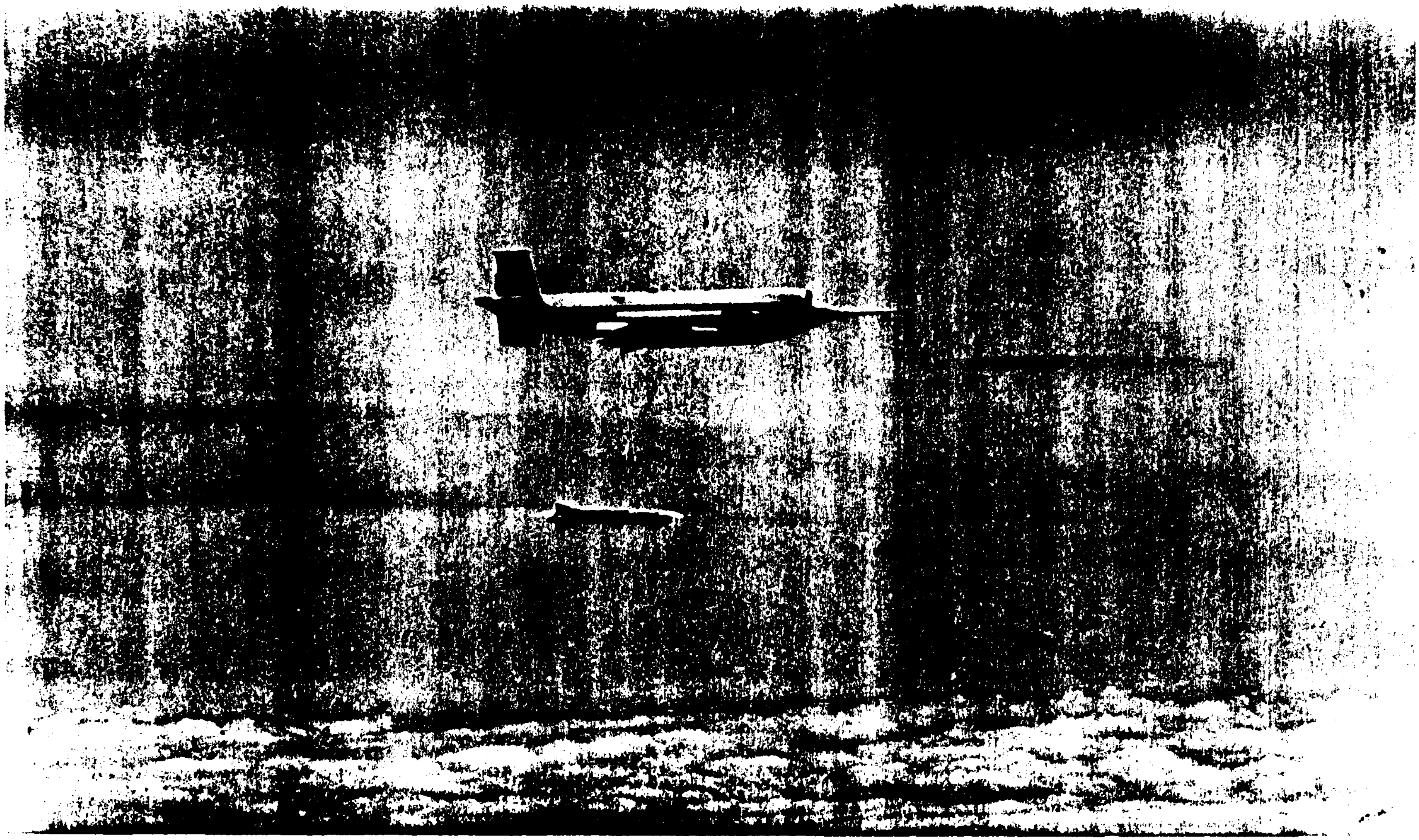
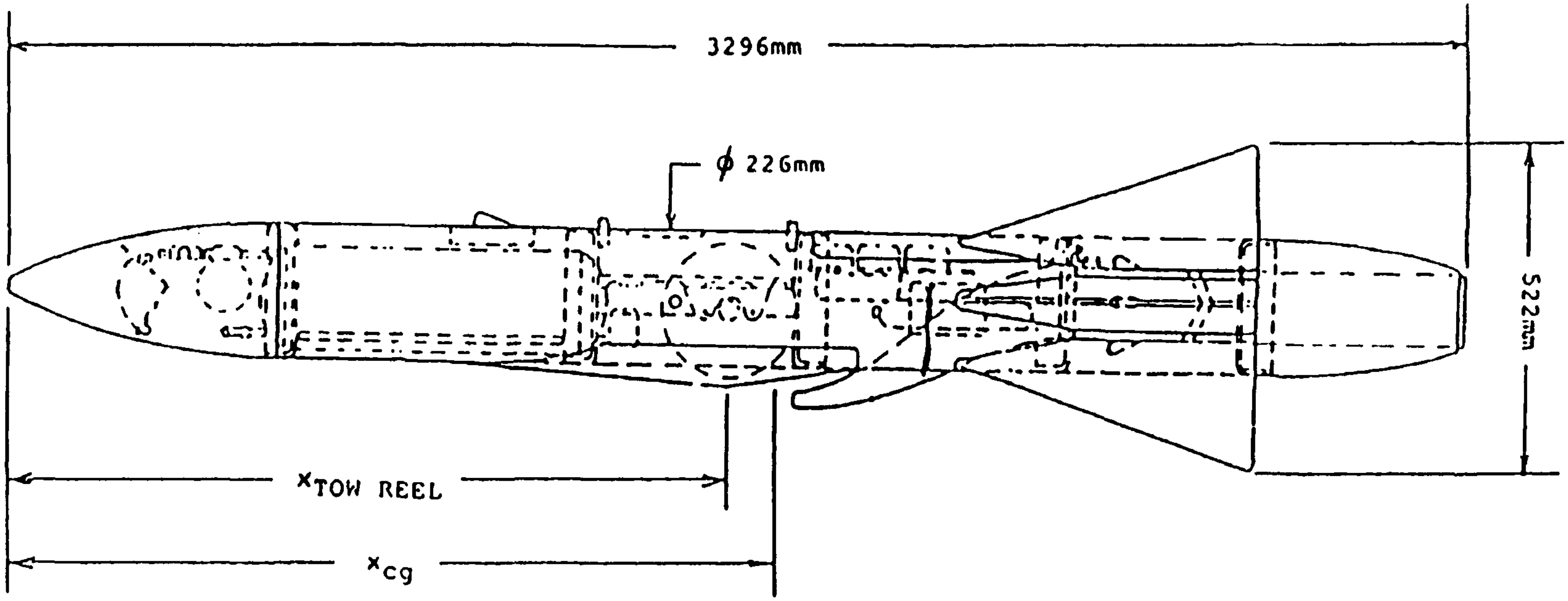


FIGURE 1 JINDIVIK/HUTTS TOWED AERIAL TARGET SYSTEM



$x_{TOW\ REEL}$ = 1637mm

No fuel mass = 28.2kg
x_{cg} = 1785mm

Full fuel mass = 38.2kg
x_{cg} = 1622mm

FIGURE 2 HAYES TPT-TA TOWED TARGET

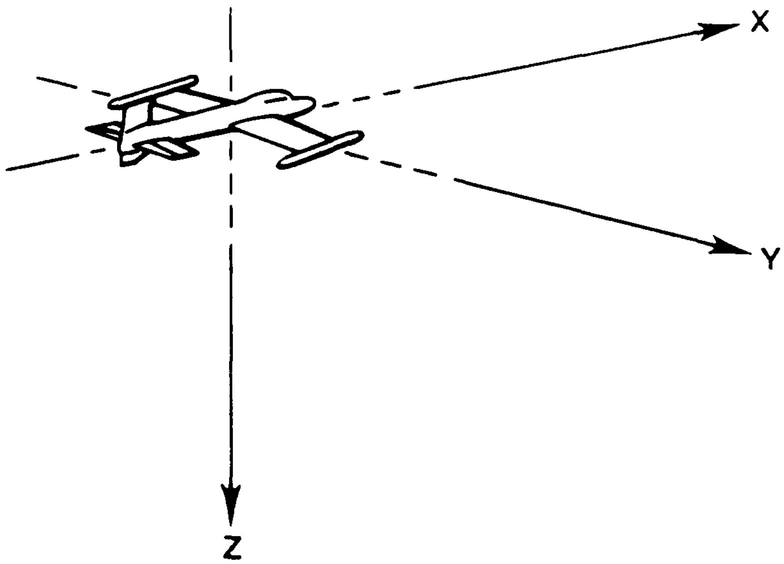
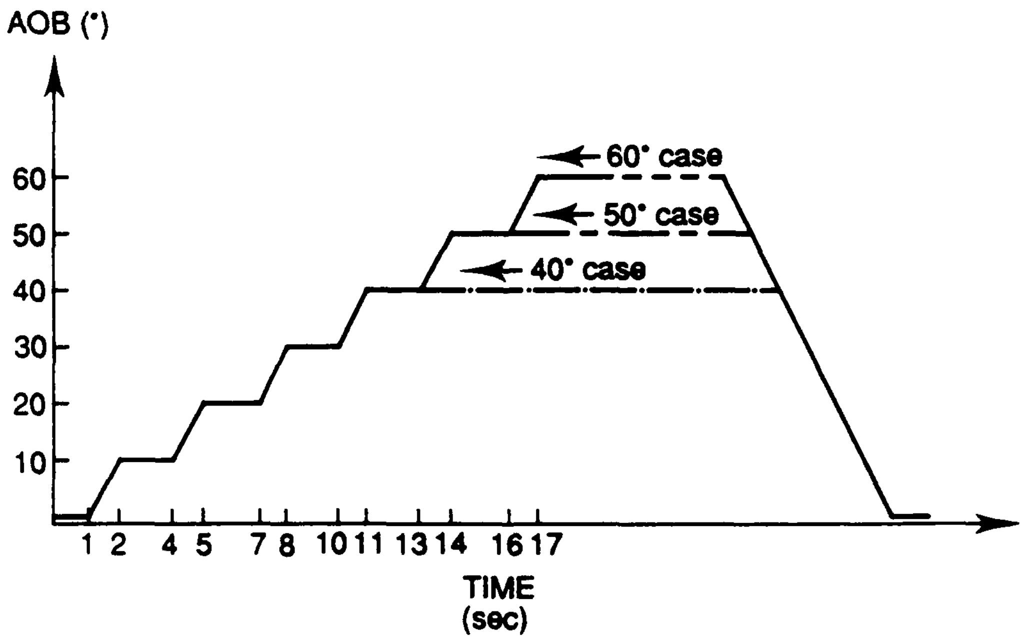


FIGURE 3 MANOEUVRE FRAME OF REFERENCE
(conventional fixed/earth axis system)



...Shown for 40,50 and 60 degrees maximum
achieved Angle Of Bank (AOB)

FIGURE 4 JINDIVIK BANKED TURN MANOEUVRE APPROXIMATION

APPENDICES

Appendix A JINDIVIK EQUIVALENT AIRSPEED CALCULATIONS

The Jindivik instrumentation, like that of most aircraft, takes direct measurements of indicated airspeed (V_{ias} or V_{cal}') and indicated altitude (H_p'). Corrections to these measurements to allow for specific instrument installation and operational biases must be made. This yields V_{cal} (calibrated airspeed) and H_p (corrected pressure altitude), respectively. These conversions are unique to each instrument installation. The next step is the conversion of calibrated airspeed to equivalent (sea level) airspeed (V_{eas}). This second conversion is a general one for converting calibrated airspeeds to equivalent airspeeds. This conversion is a general (non aircraft/installation specific) one.

Reference 11 contains the method and conversion charts for performing the above conversions. Following the method of this reference yields the results tabulated below (note that for CBAS, equivalent airspeed in metres/sec, found by multiplying value in Knots by 0.514, is used to be consistent with using a air density of 1.225 kg/m^3 (sea level) in every flight case).

Table A-1 - Converted measurements results

V_{ias} (H_p')	V_{cal} (H_p)	V_{eas}
KIAS (ft)	Knots (ft)	Knots [m/s]
200 (2000)	204.2 (2090)	204.0 [105]
250 (2000)	255.6 (2140)	255.5 [131]
300 (2000)	306.7 (2215)	306.7 [158]
350 (2000)	358.0 (2300)	357.8 [184]
430 (2000)	439.7 (2480)	439.5 [226]

Appendix B TOW CABLE DATA

Tow cable data (assumed values)

Diameter (mm)	1.63
Normal drag coefficient **	1.1
Tangential drag coefficient	0.02
Mass/unit length (kg/m)	0.0163
Density (kg/m^3)	7800

** assumed based on presented (bluff) area.

Appendix C HAYES TPT-5A TOWED BODY DATA

Mechanical properties (measured)

Target mass (kg)	38.2
Body cross-sectional area (m^2)	0.04
Body length (m)	3.290
Towpoint x-coordinate (m)	0.170
Towpoint z-coordinate (m)	0.113
Roll moment of inertia ($kg.m^2$)	0.292
Pitch " " " "	16.4
Yaw " " " "	16.4
Product of inertia, I_{xz} "	0 (assumed)

Aerodynamic derivatives (theoretically calculated)

Drag coefficient	CX0	-0.50
Side force coeff (/radian)	CY1	-17.2
Lift coefficient (/radian)	CZ1	-17.4
Rolling moment (/radian)	CL1	0
Pitching moment	CM0	-0.00107
Pitching moment (/radian)	CM1	-4.60
Yawing moment (/radian)	CN1	4.49

Rotary derivatives (theoretically calculated)

Side force due to yaw rate (/radian)	YR	4.49
Lift force due to pitch rate (/radian)	ZQ	-4.60
Roll moment due to roll rate (/radian)	LP	-0.024
Roll moment due to yaw rate (/radian)	LR	0
Pitch moment due to pitch rate (/radian)	MQ	-1.219
Yaw moment due to roll rate (/radian)	NP	0
Yaw moment due to yaw rate (/radian)	NR	-1.17

note 1 Derivatives based on body cross sectional area.

note 2 Moment arm used to normalise moment coefficients is distance from target centre of gravity to aerodynamic centre of tail fins. The tail arm (L_T) has been calculated as 0.703 metres.

Appendix D

JINDIVIK/HAYES TPT-5A MANOEUVRE PLAN-VIEWS
(XY plots)

Included Flight Cases (FC) **shown bold** ...

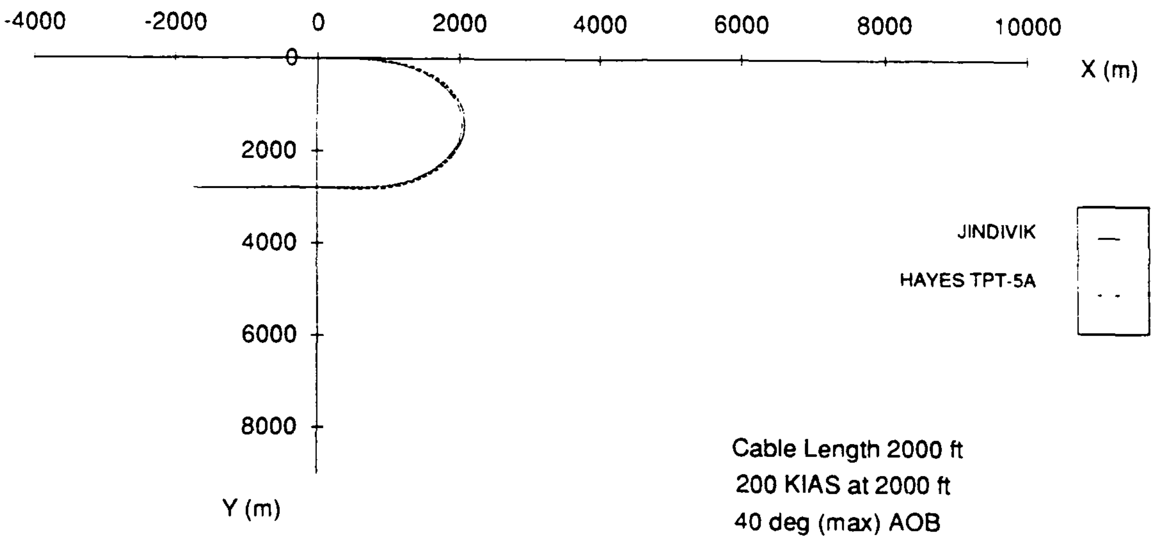
FC111	FC211	**FC311**	FC411
FC112	FC212	FC312	FC412
FC113	FC213	**FC313**	FC413
FC121	FC221	FC321	FC421
FC122	FC222	FC322	FC422
FC123	FC223	FC323	FC423
FC131	FC231	FC331	FC431
FC132	FC232	FC332	FC432
FC133	FC233	FC333	FC433
FC141	FC241	**FC341**	FC441
FC142	FC242	FC342	FC442
FC143	FC243	**FC343**	FC443

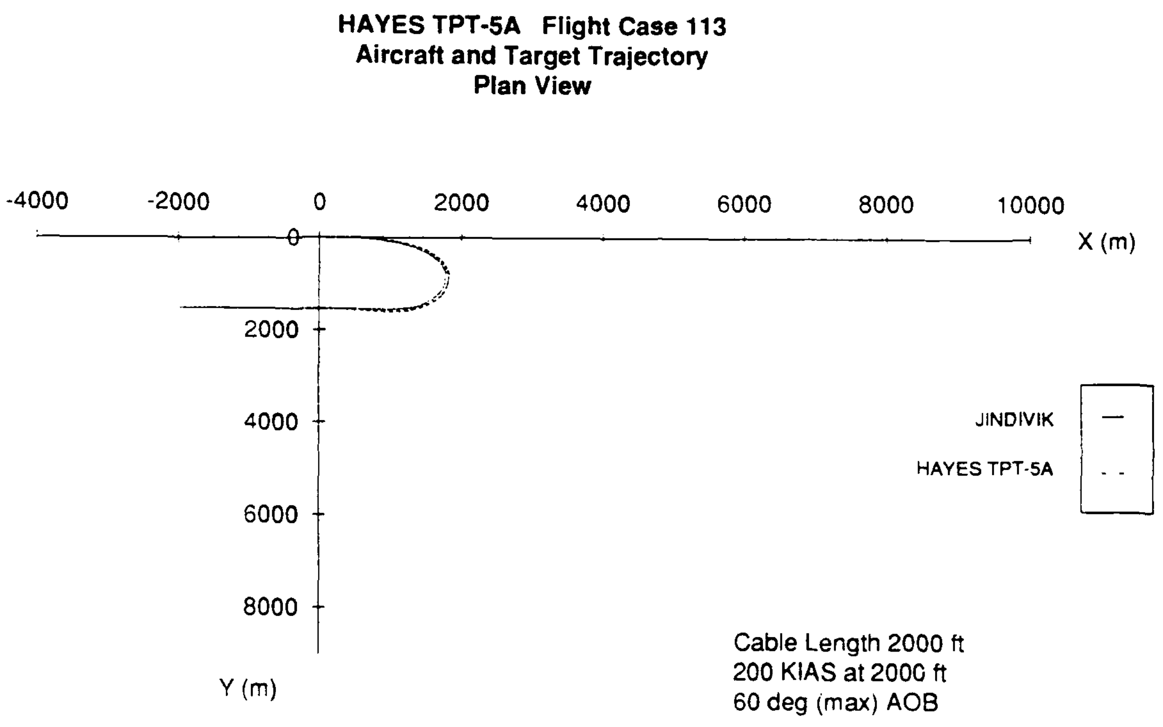
... also **included**

FC152

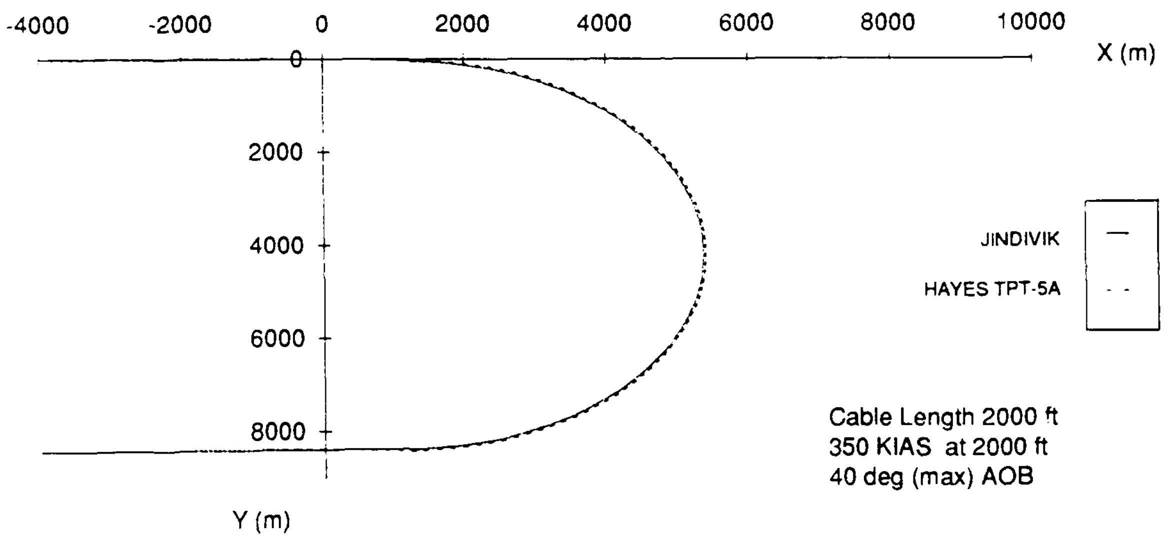
note order of appearance of results ... read down columns, starting at left hand (1st) column. Refer Table 1 for coding of Flight Cases.

HAYES TPT-5A Flight Case 111
Aircraft and Target Trajectory
Plan View

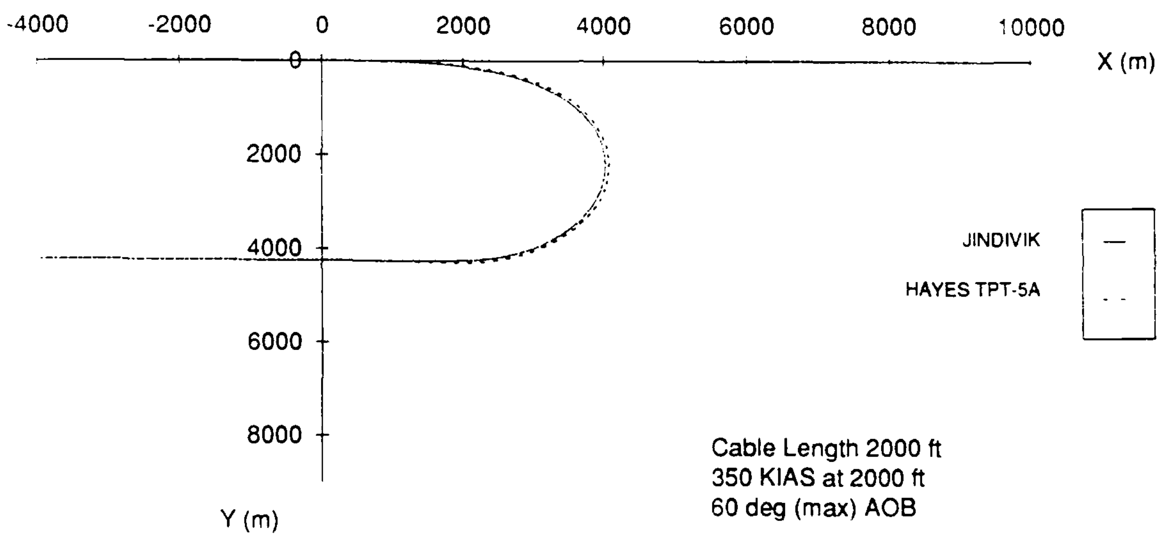



HAYES TPT-5A Flight Case 113
Aircraft and Target Trajectory
Plan View
-4000
-2000
0
2000
4000
6000
8000
10000
X (m)
0
2000
4000
6000
8000
Y (m)
JINDIVIK
HAYES TPT-5A
Cable Length 2000 ft
200 KIAS at 2000 ft
60 deg (max) AOB

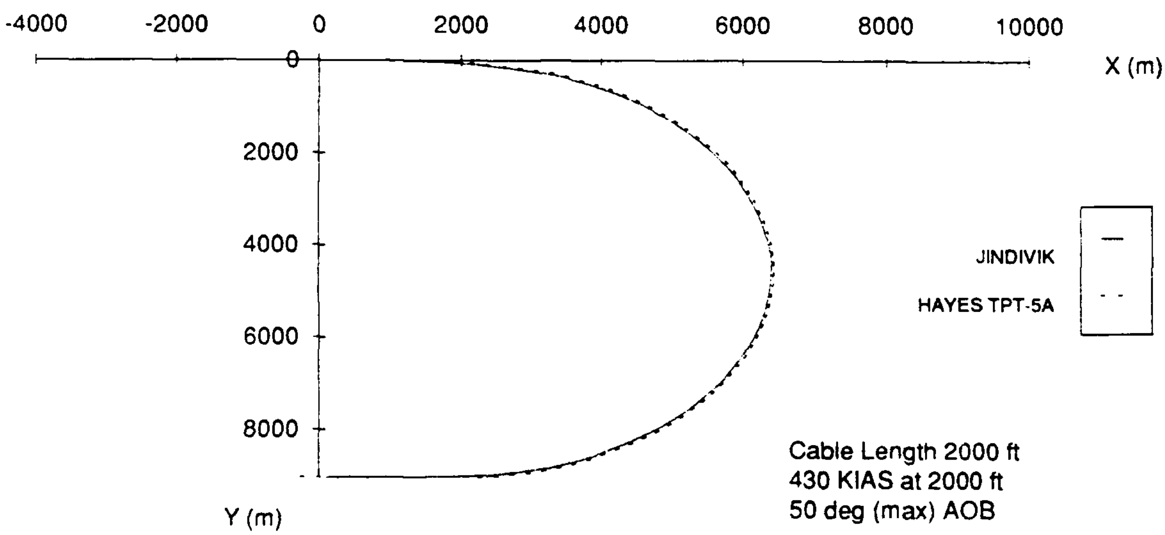
HAYES TPT-5A Flight Case 141
Aircraft and Target Trajectory
Plan View



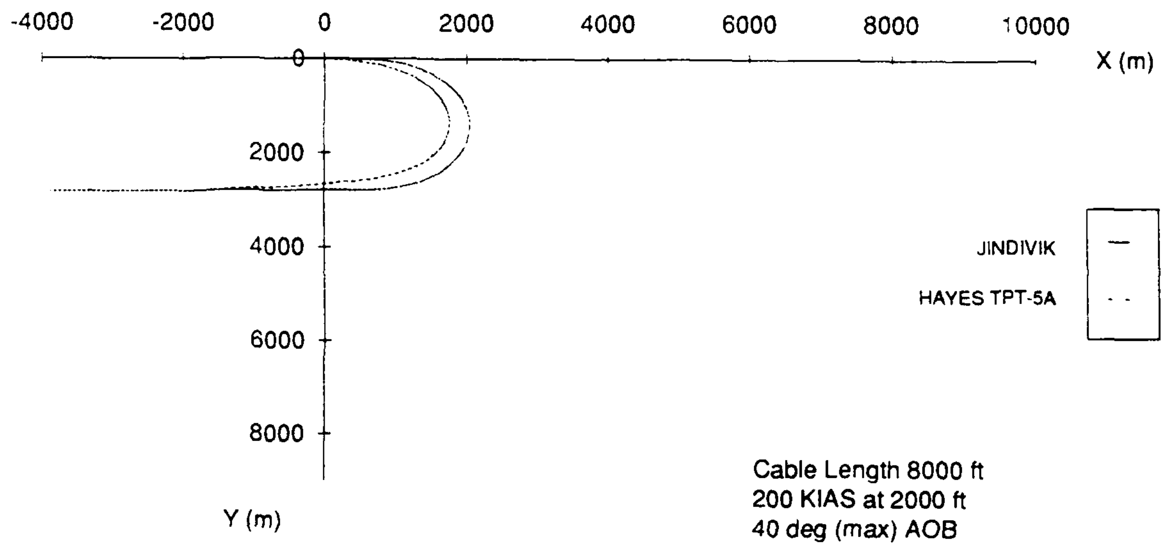
HAYES TPT-5A Flight Case 143
Aircraft and Target Trajectory
Plan View



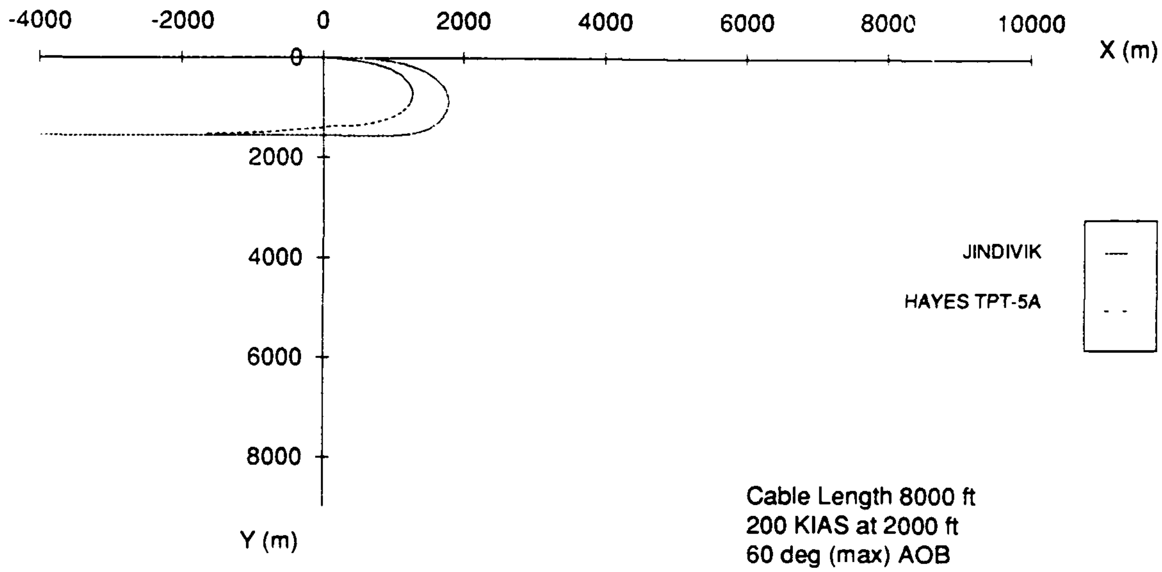
HAYES TPT-5A Flight Case 152
Aircraft and Target Trajectory
Plan View



HAYES TPT-5A Flight Case 311
Aircraft and Target Trajectory
Plan View

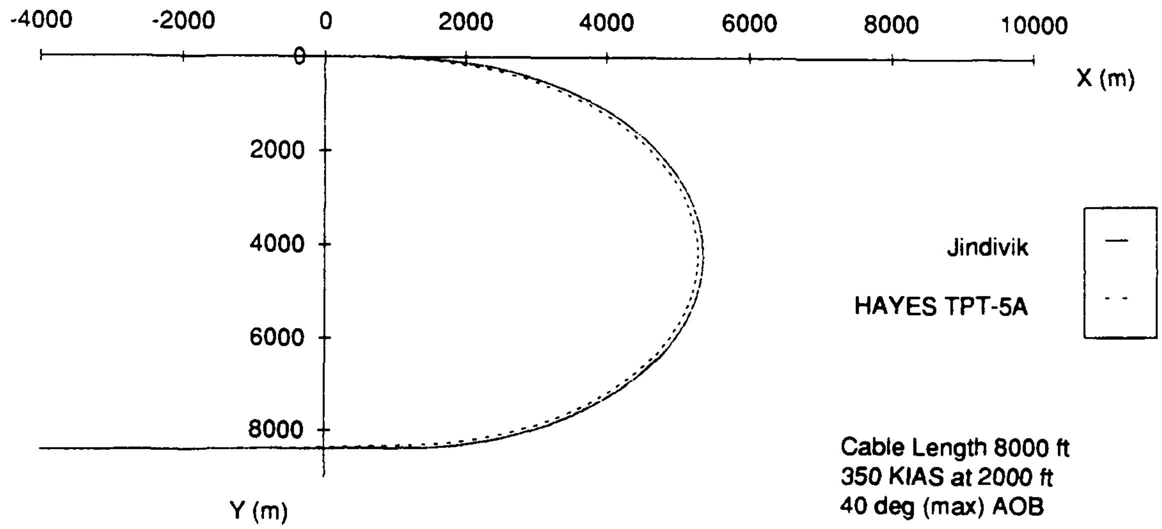


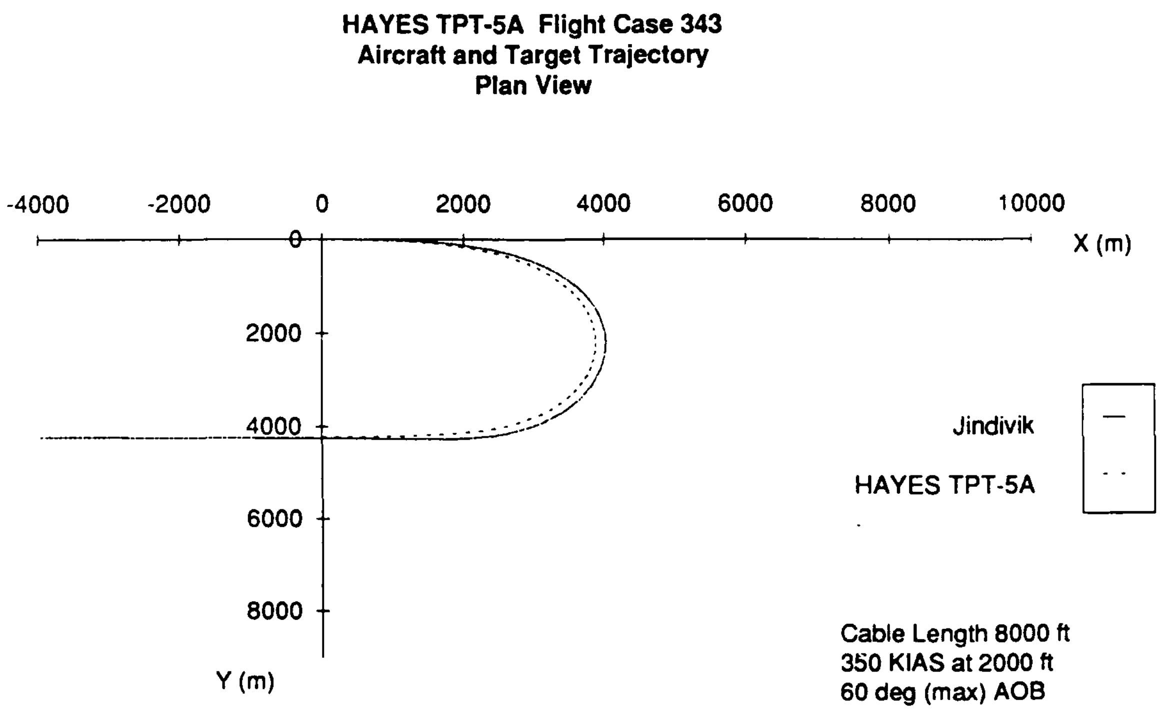
HAYES TPT-5A Flight Case 313
Aircraft and Target Trajectory
Plan View



Cable Length 8000 ft
200 KIAS at 2000 ft
60 deg (max) AOB

HAYES TPT-5A Flight Case 341
Aircraft and Target Trajectory
Plan View




HAYES TPT-5A Flight Case 343
Aircraft and Target Trajectory
Plan View
-4000
-2000
0
2000
4000
6000
8000
10000
X (m)
0
2000
4000
6000
8000
Y (m)
Jindivik
HAYES TPT-5A
Cable Length 8000 ft
350 KIAS at 2000 ft
60 deg (max) AOB

Appendix E JINDIVIK/HAYES TPT-5A MANOEUVRE SIDE-ELEVATIONS (XZ plots)

Included Flight Cases (FC) **shown bold** ...

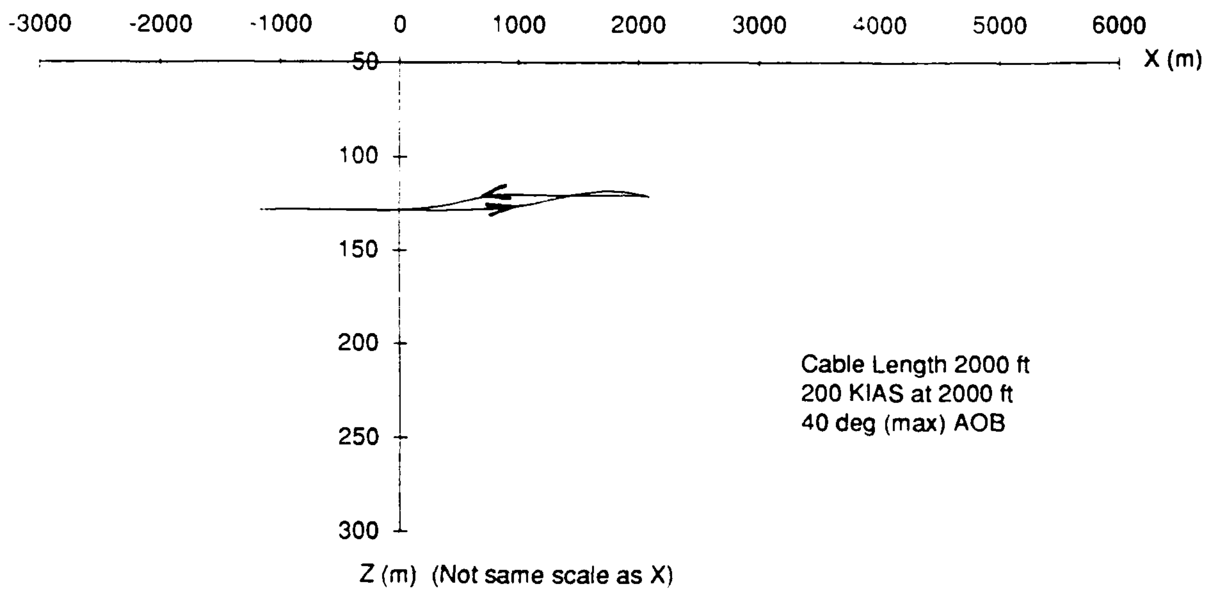
FC111	FC211	**FC311**	FC411
FC112	FC212	FC312	FC412
FC113	FC213	**FC313**	FC413
FC121	FC221	FC321	FC421
FC122	FC222	FC322	FC422
FC123	FC223	FC323	FC423
FC131	FC231	FC331	FC431
FC132	FC232	FC332	FC432
FC133	FC233	FC333	FC433
FC141	FC241	**FC341**	FC441
FC142	FC242	FC342	FC442
FC143	FC243	**FC343**	FC443

... also **included**

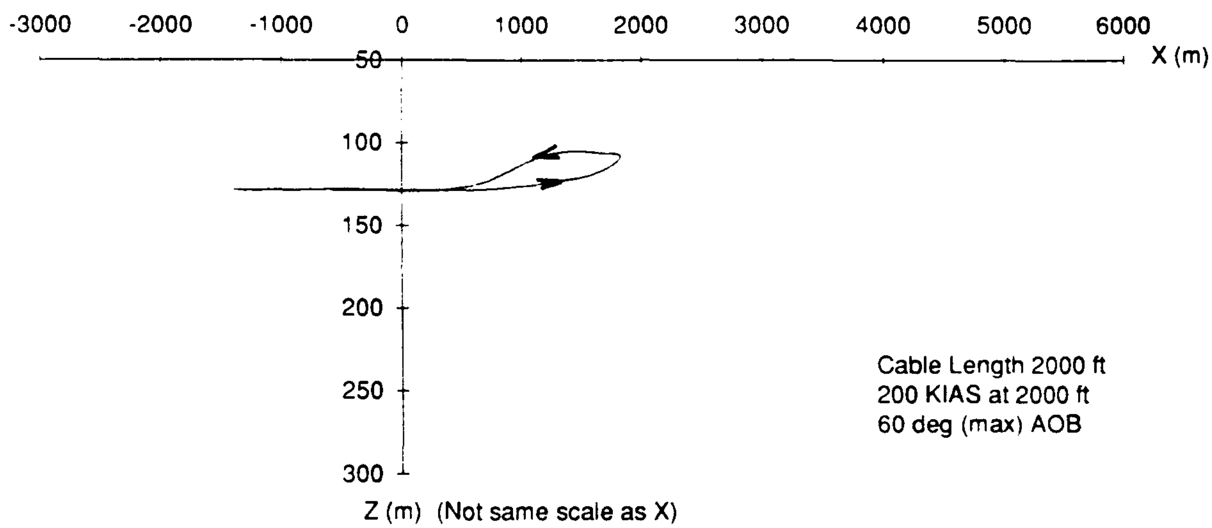
FC152

note as for Appendix D.

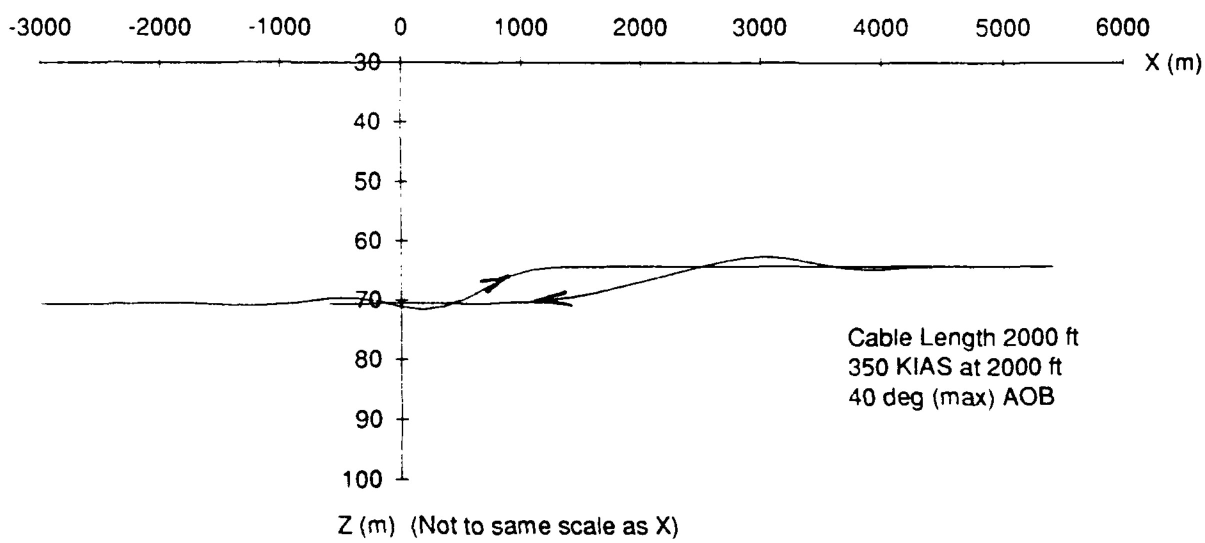
HAYES TPT-5A Flight Case 111
Target Trajectory Side View



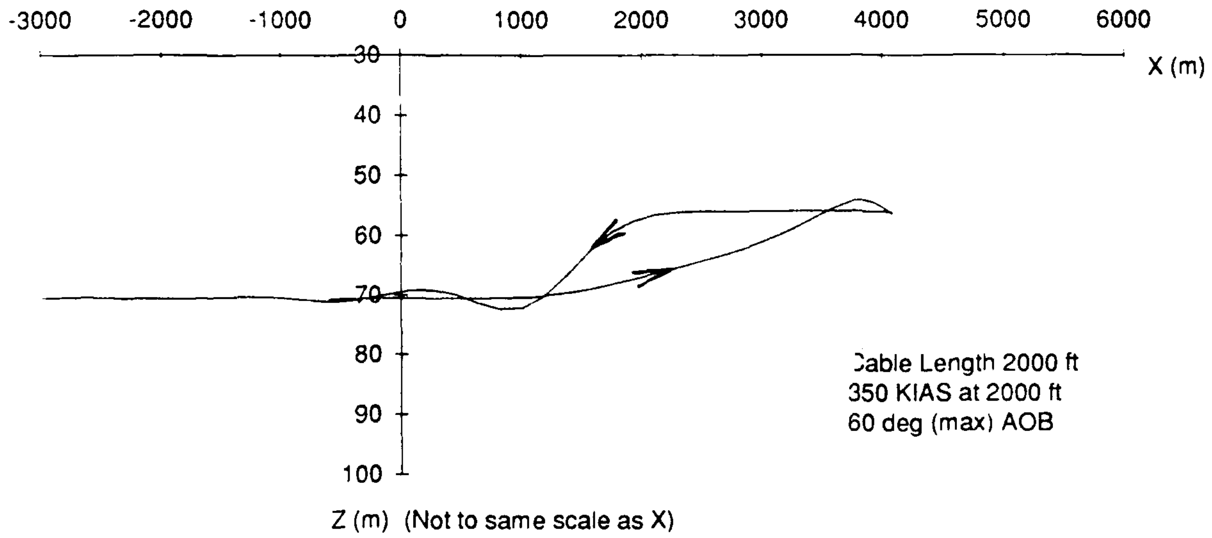
HAYES TPT-5A Flight Case 113
Target Trajectory Side View



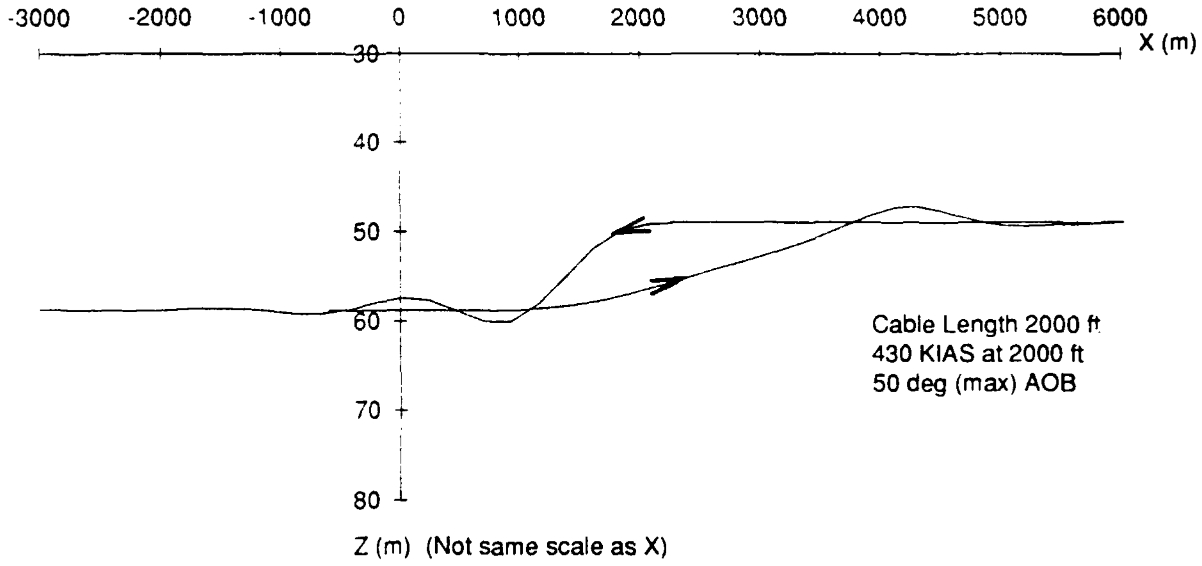
HAYES TPT-5A Flight Case 141
Target Trajectory Side View



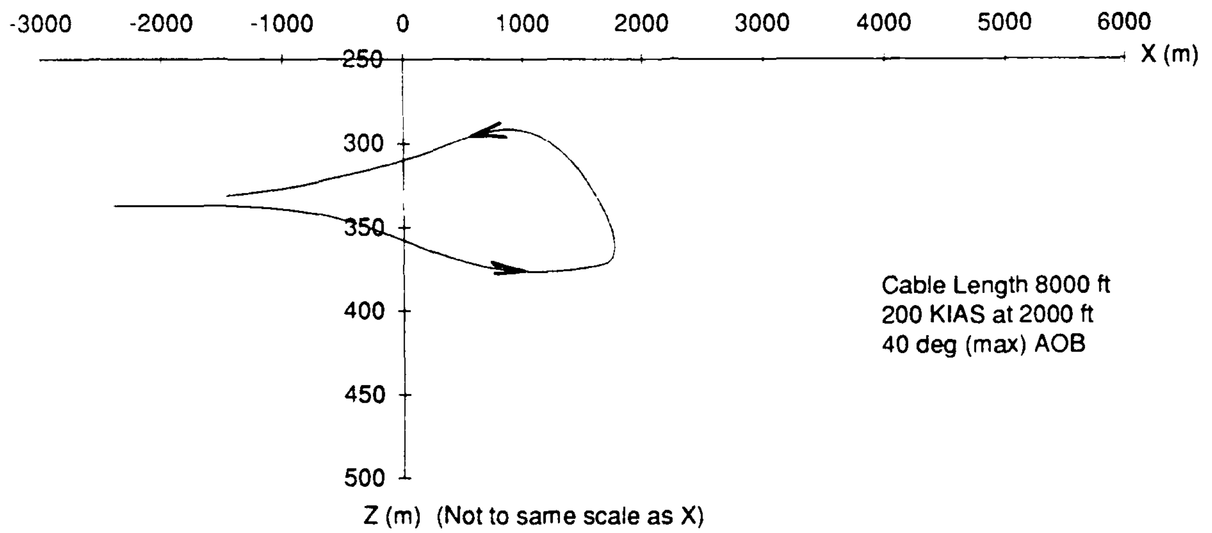
HAYES TPT-5A Flight Case 143
Target Trajectory Side View



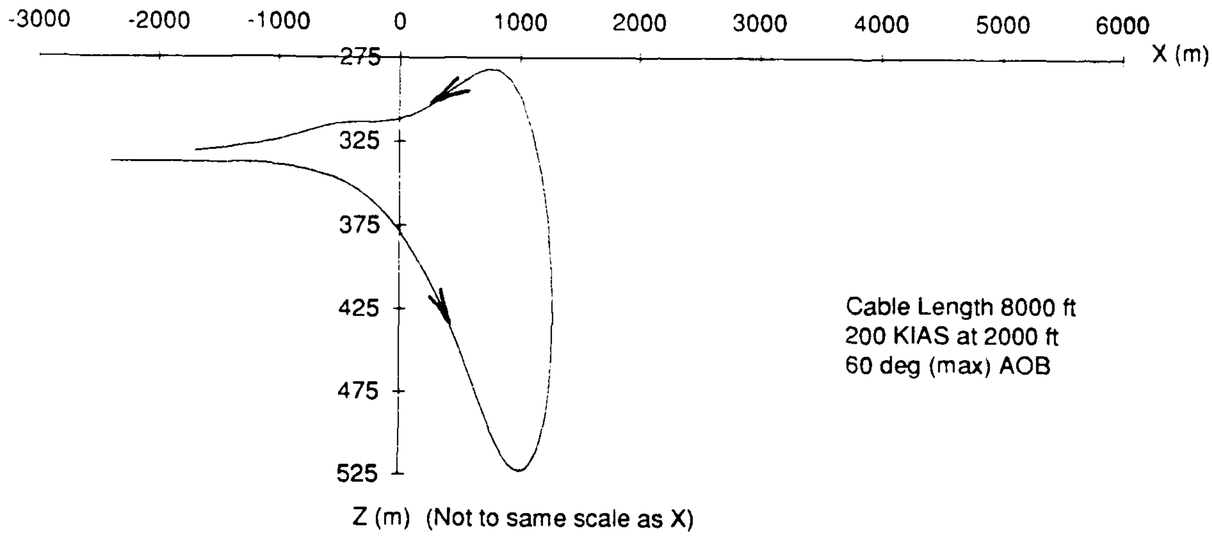
HAYES TPT-5A Flight Case 152
Target Trajectory Side View



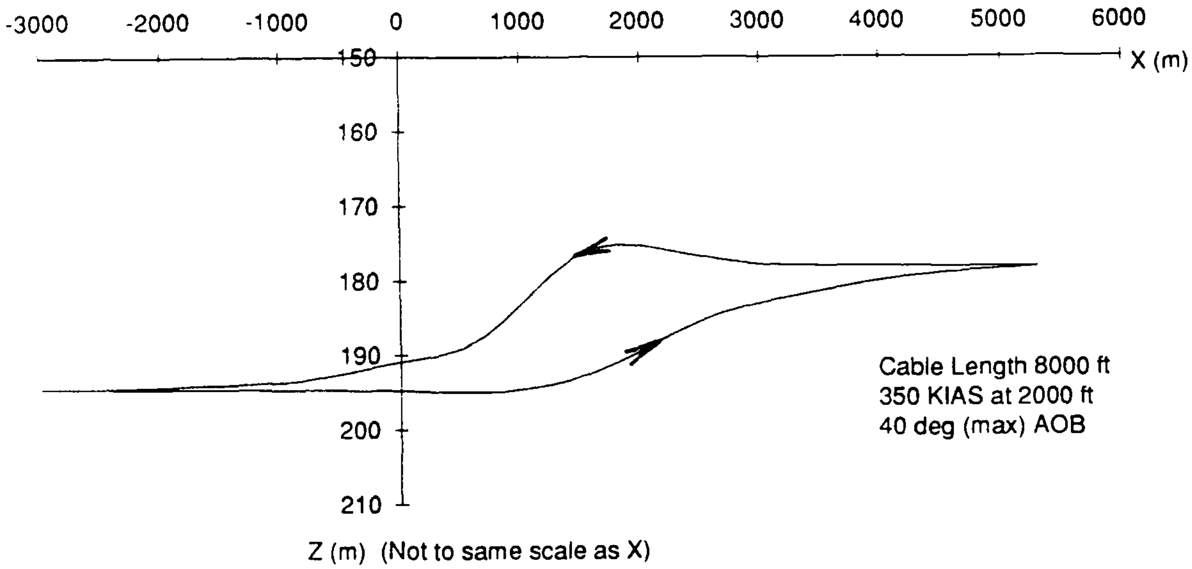
HAYES TPT-5A Flight Case 311
Target Trajectory Side View



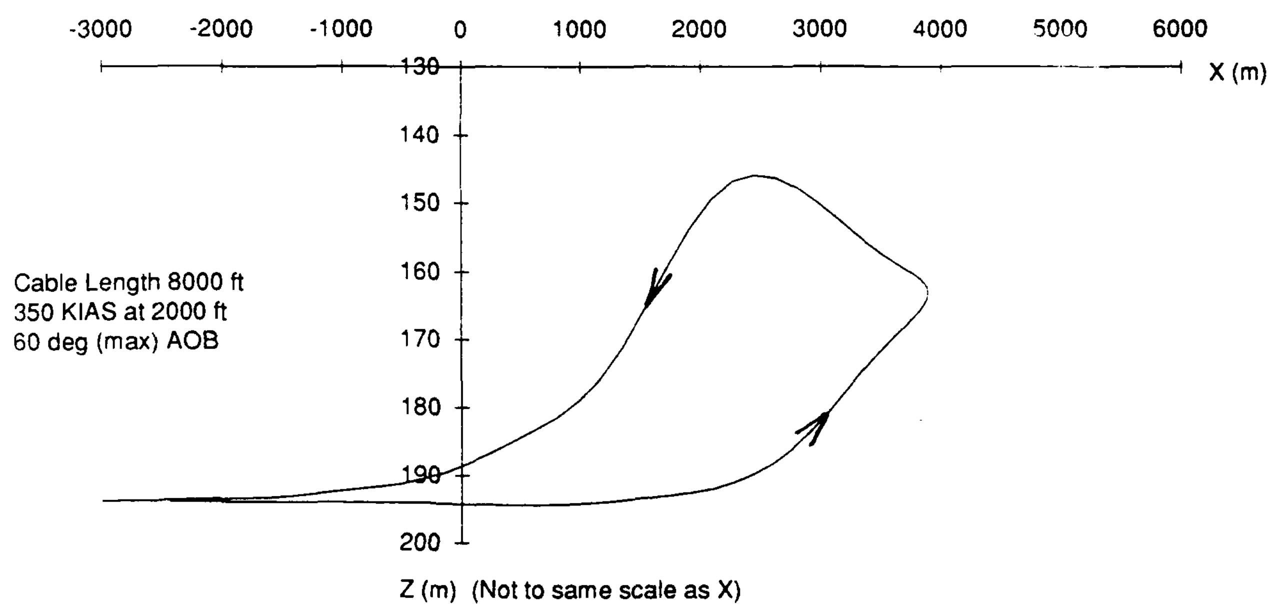
HAYES TPT-5A Flight Case 313
Target Trajectory Side View



HAYES TPT-5A Flight Case 341
Target Trajectory Side View



HAYES TPT-5A Flight Case 343
Target Trajectory Side View



Appendix F TOW CABLE TENSION PLOTS

Included Flight Cases (FC) **shown bold** ...

FC111	FC211	**FC311**	FC411
FC112	FC212	FC312	FC412
FC113	FC213	**FC313**	FC413
FC121	FC221	FC321	FC421
FC122	FC222	FC322	FC422
FC123	FC223	FC323	FC423
FC131	FC231	FC331	FC431
FC132	FC232	FC332	FC432
FC133	FC233	FC333	FC433
FC141	FC241	**FC341**	FC441
FC142	FC242	FC342	FC442
FC143	FC243	**FC343**	FC443

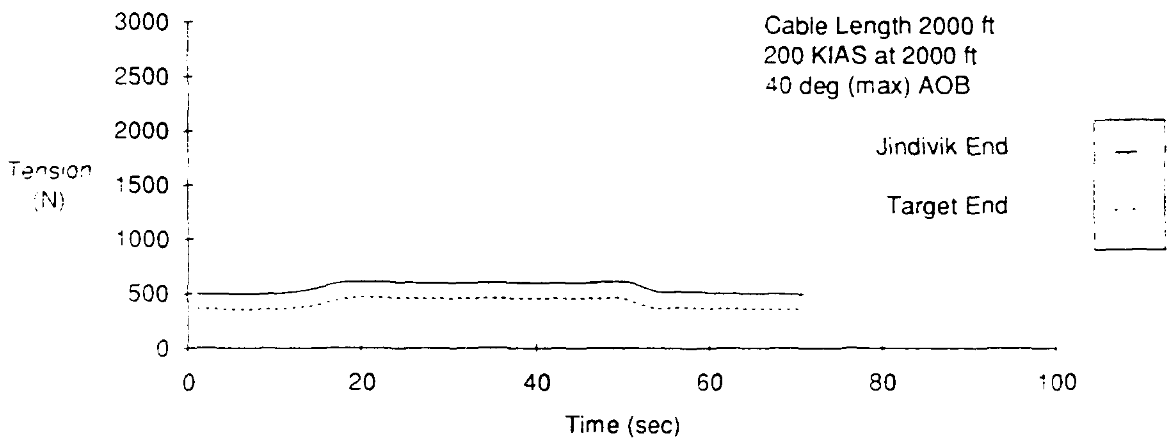
... also **included**

FC152

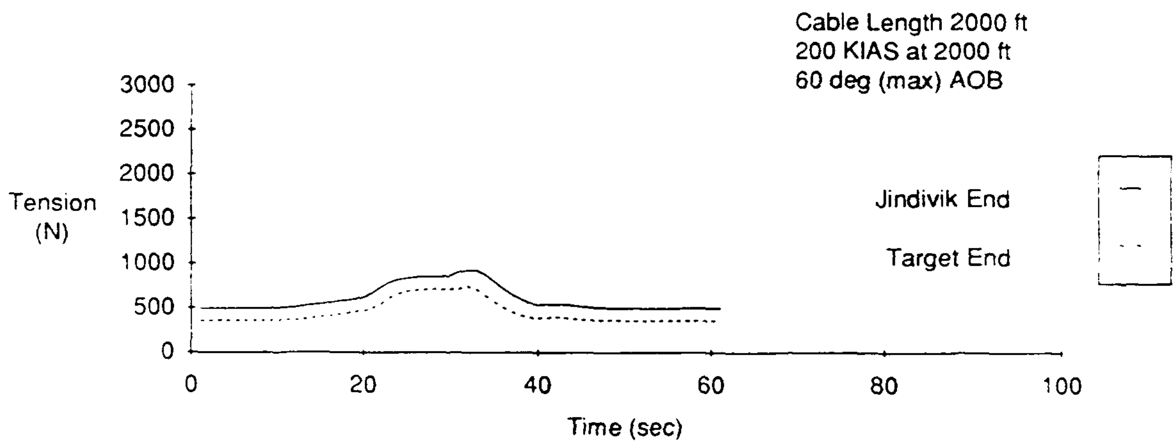
note 1 As for Appendix D.

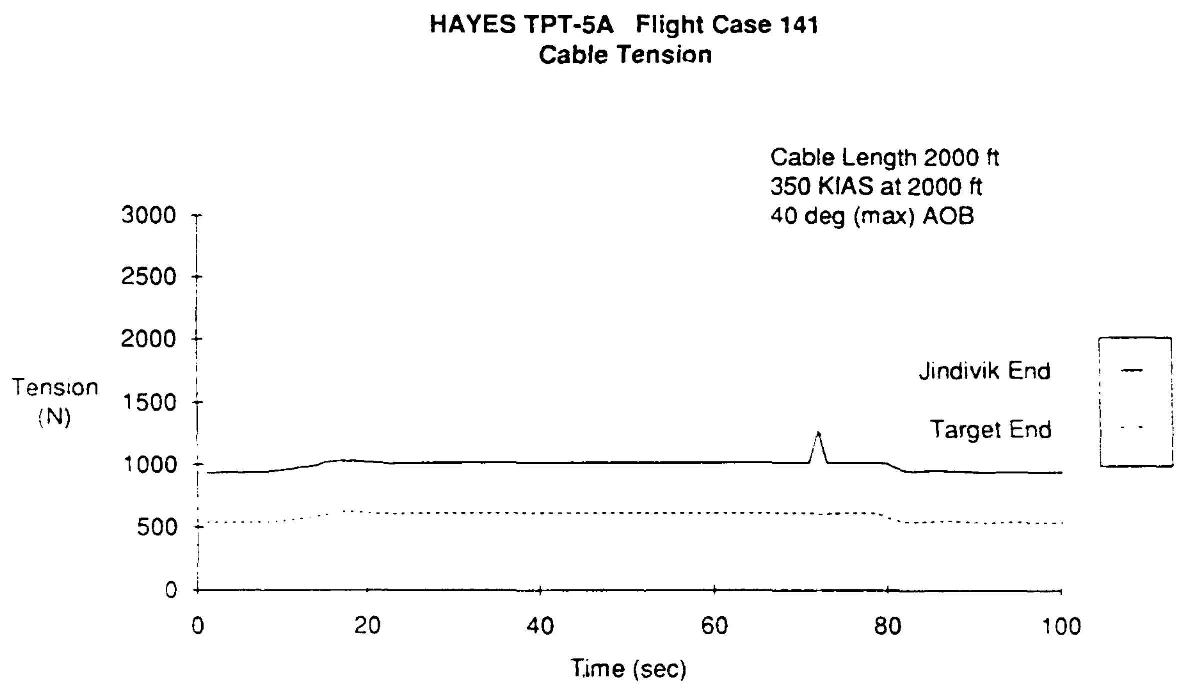
note 2 Upper line on tension plot represents cable tension at the towing vehicle (Jindivik) end, lower line represents cable tension at the towed body (Hayes TPT-5A) end.

HAYES TPT-5A Flight Case 111
Cable Tension

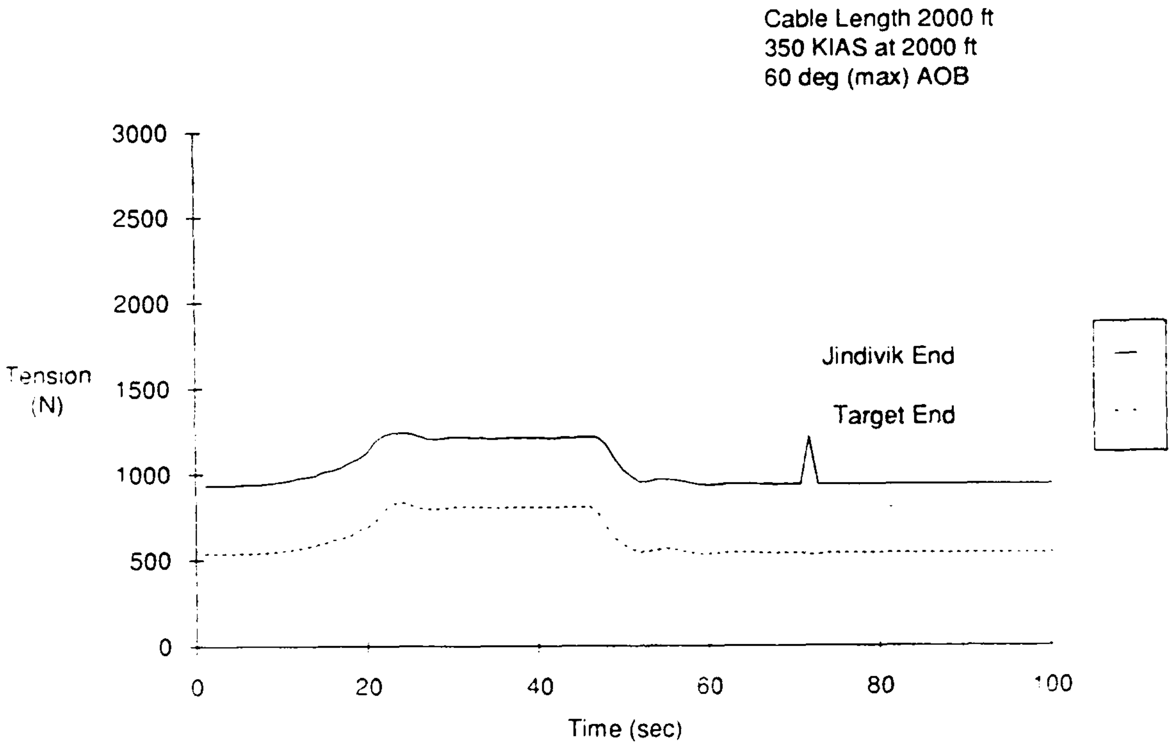


HAYES TPT-5A Flight Case 113
Cable Tension

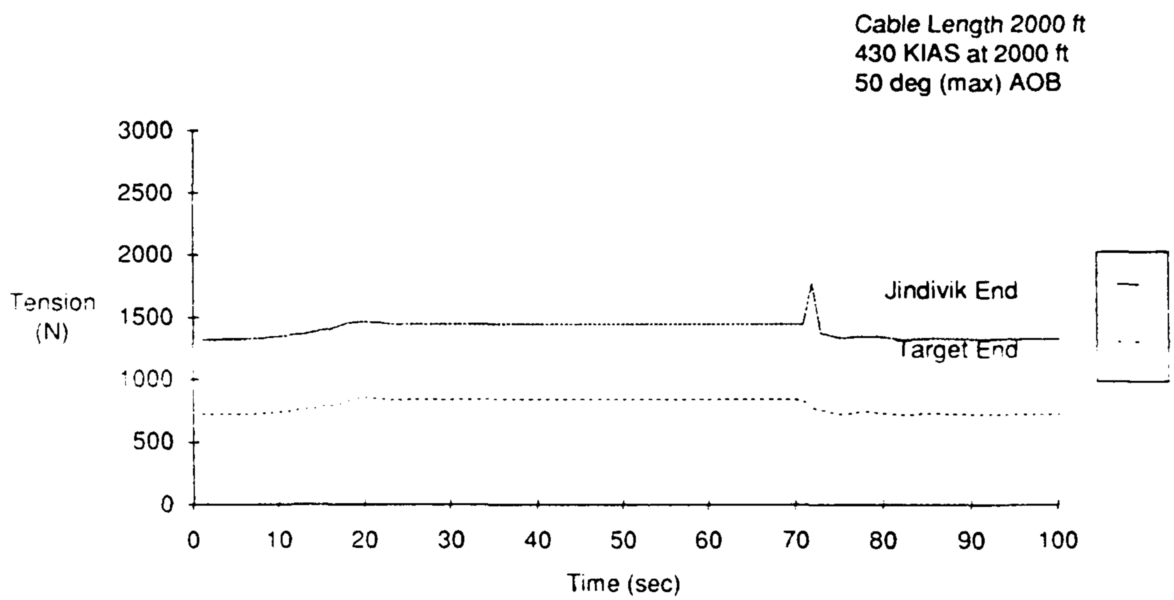



HAYES TPT-5A Flight Case 141
Cable Tension
Cable Length 2000 ft
350 KIAS at 2000 ft
40 deg (max) AOB
Tension (N)
3000
2500
2000
1500
1000
500
0
Jindivik End
Target End
0
20
40
60
80
100
Time (sec)

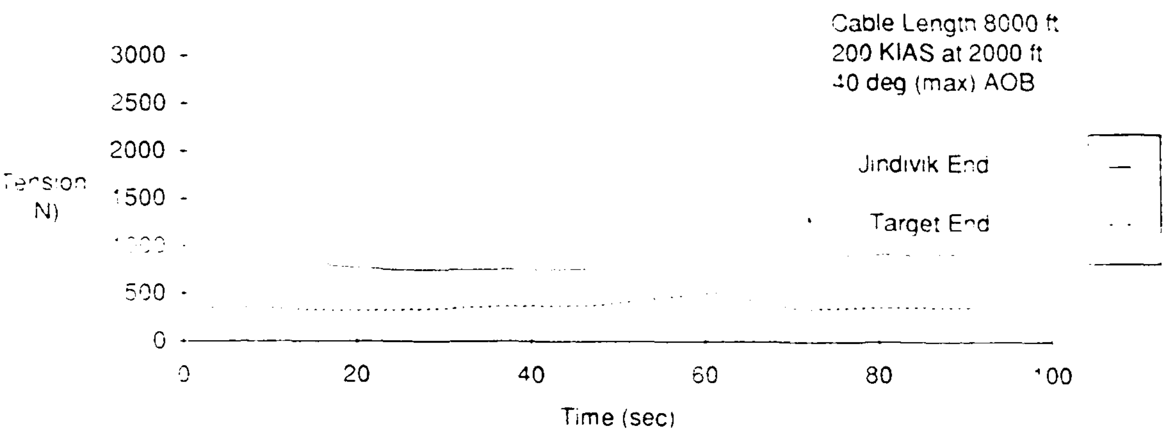
HAYES TPT-5A Flight Case 143
Cable Tension



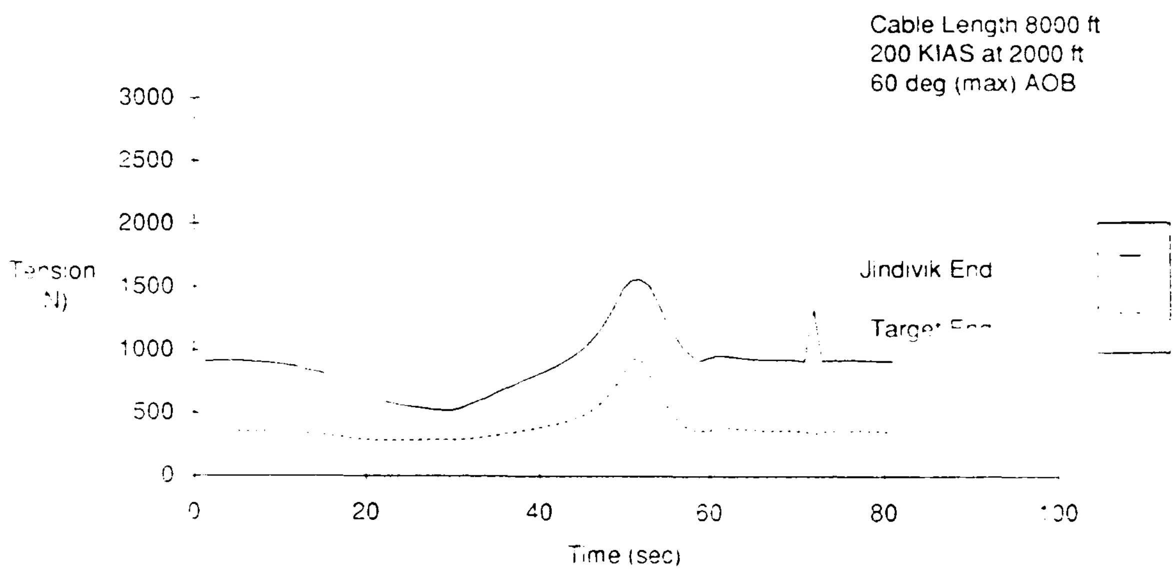
HAYES TPT-5A Flight Case 152
Cable Tension

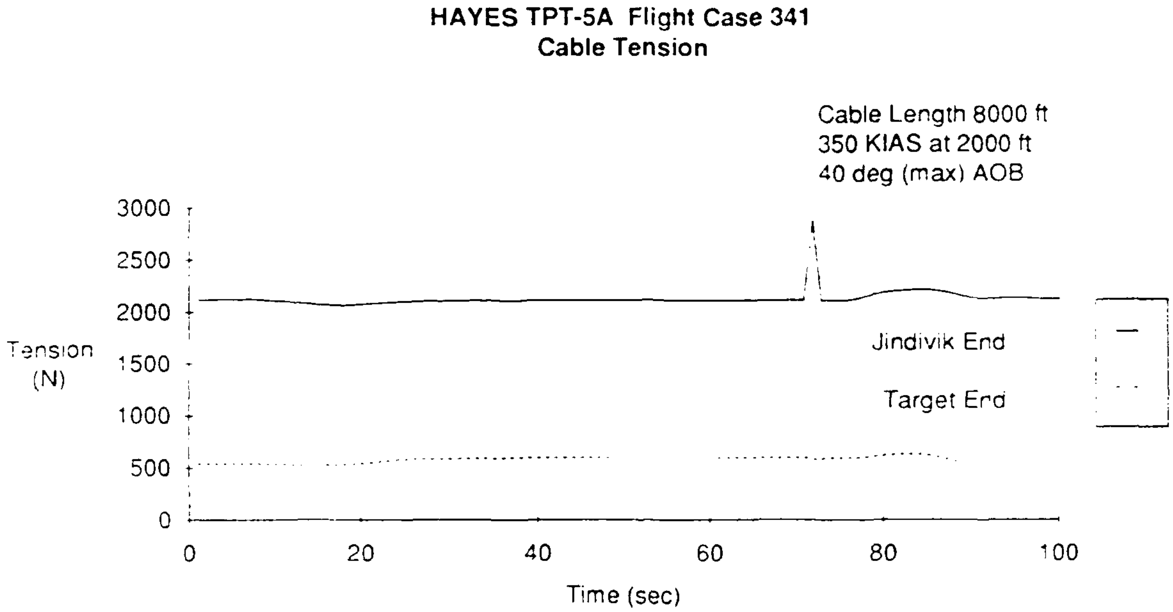


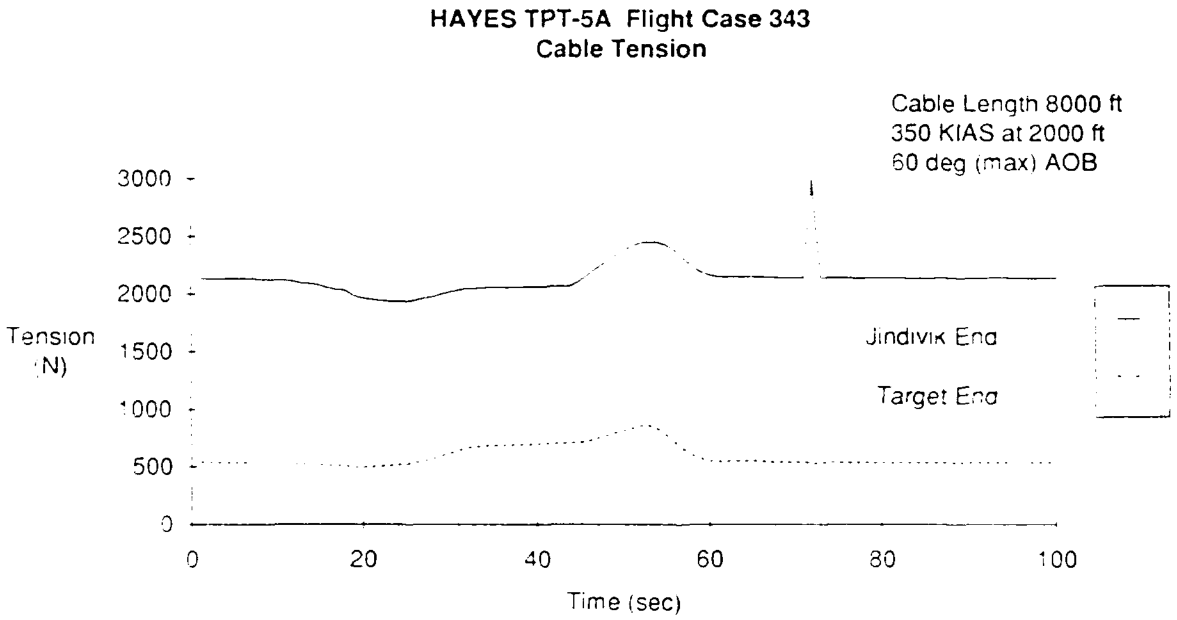
HAYES TPT-5A Flight Case 311
Cable Tension



HAYES TPT-5A Flight Case 313
Cable Tension




HAYES TPT-5A Flight Case 341
Cable Tension
Cable Length 8000 ft
350 KIAS at 2000 ft
40 deg (max) AOB
3000
2500
2000
1500
1000
500
0
Tension (N)
0
20
40
60
80
100
Time (sec)
Jindivik End
Target End


HAYES TPT-5A Flight Case 343
Cable Tension
Cable Length 8000 ft
350 KIAS at 2000 ft
60 deg (max) AOB
Tension (N)
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
Time (sec)
Jindivik End
Target End

Appendix G TPT-5A ABSOLUTE ACCELERATION PLOTS

Included Flight Cases (FC) **shown bold** ...

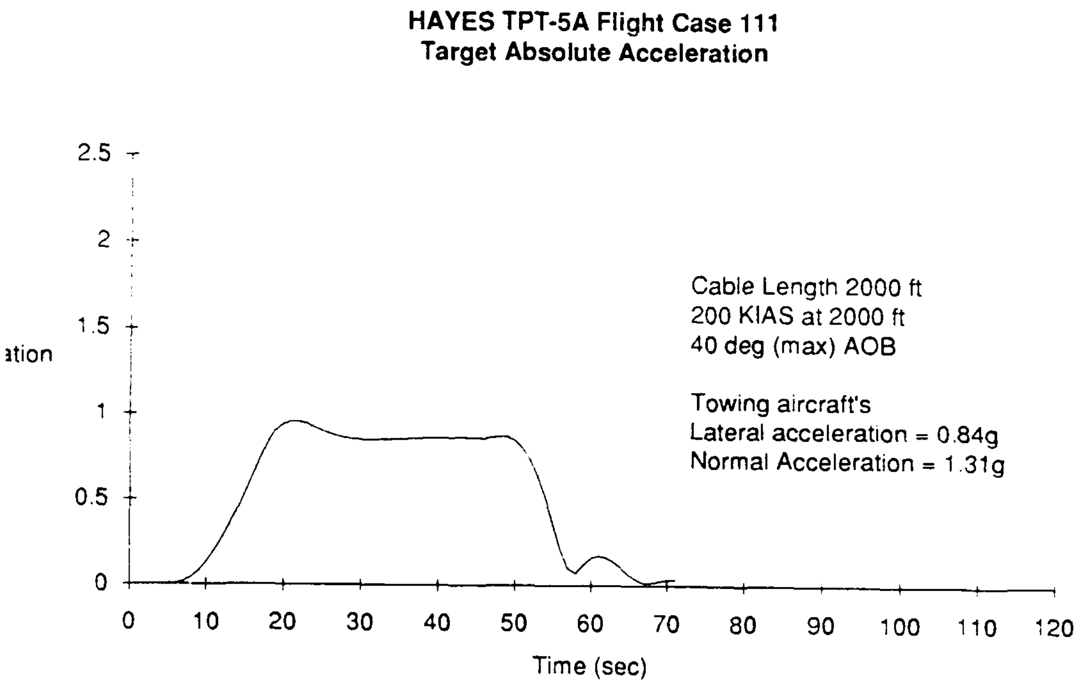
FC111	FC211	**FC311**	FC411
FC112	FC212	FC312	FC412
FC113	FC213	**FC313**	FC413
FC121	FC221	FC321	FC421
FC122	FC222	FC322	FC422
FC123	FC223	FC323	FC423
FC131	FC231	FC331	FC431
FC132	FC232	FC332	FC432
FC133	FC233	FC333	FC433
FC141	FC241	**FC341**	FC441
FC142	FC242	FC342	FC442
FC143	FC243	**FC343**	FC443

... also **included**

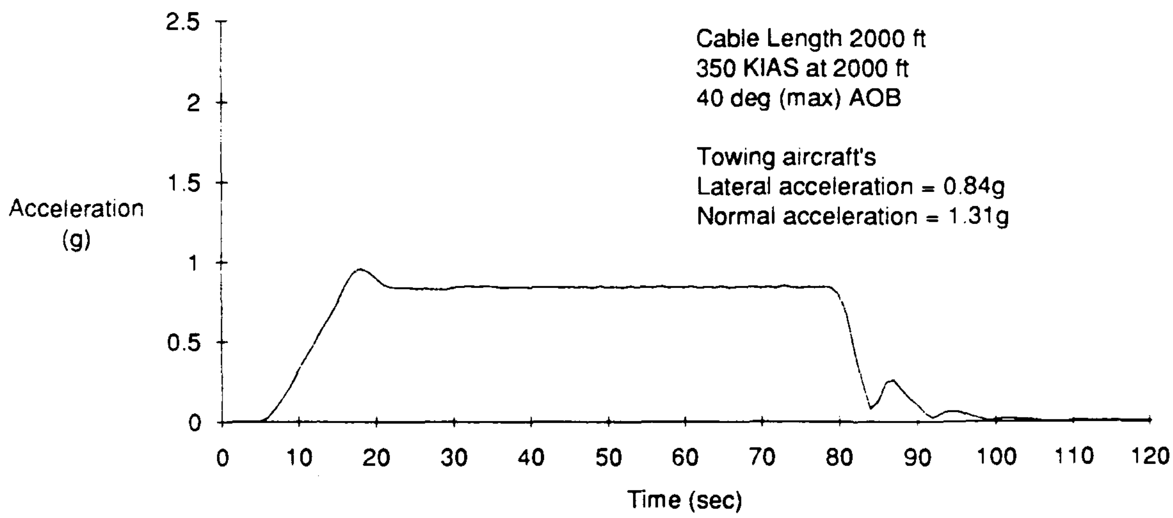
FC152

note 1 As for Appendix D.

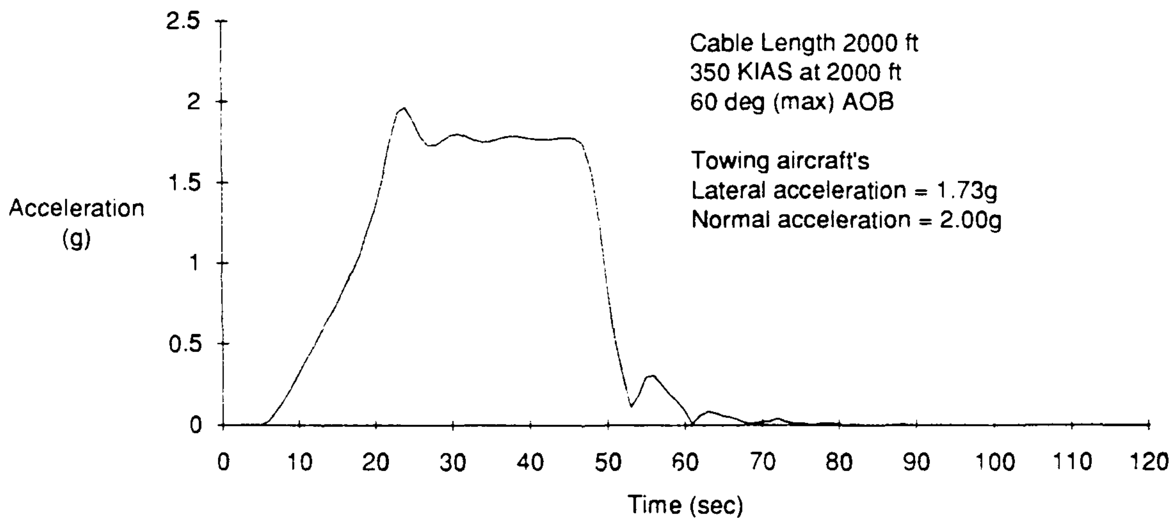
note 2 The "absolute acceleration" is the magnitude of the vector sum of the towed body X,Y and Z acceleration components (ie. gravity component is not included).


HAYES TPT-5A Flight Case 111
Target Absolute Acceleration
ation
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70
80
90
100
110
120
Time (sec)
Cable Length 2000 ft
200 KIAS at 2000 ft
40 deg (max) AOB
Towing aircraft's
Lateral acceleration = 0.84g
Normal Acceleration = 1.31g

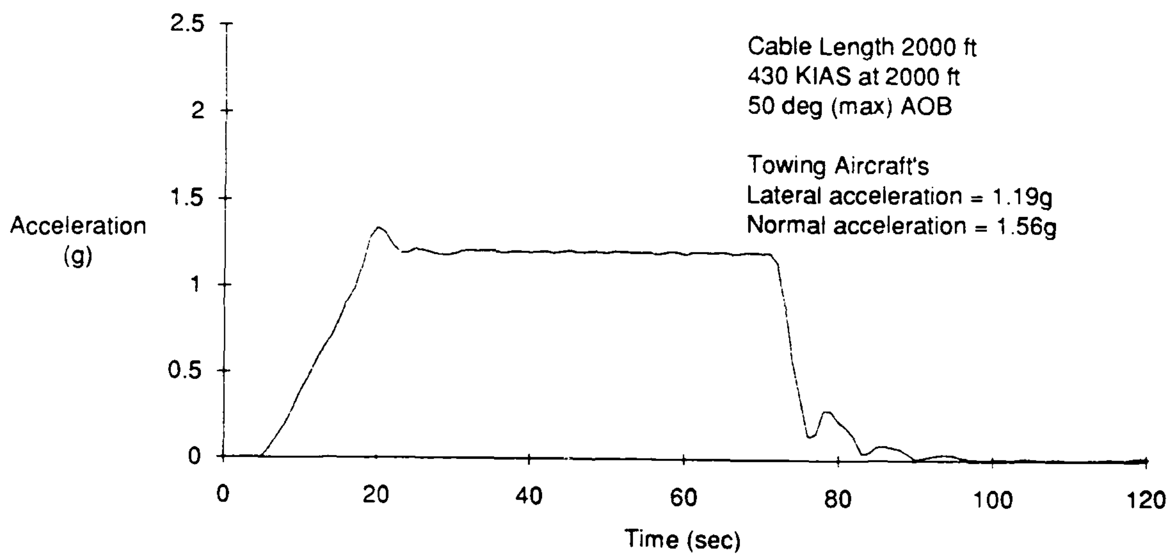
HAYES TPT-5A Flight Case 141
Target Absolute Acceleration



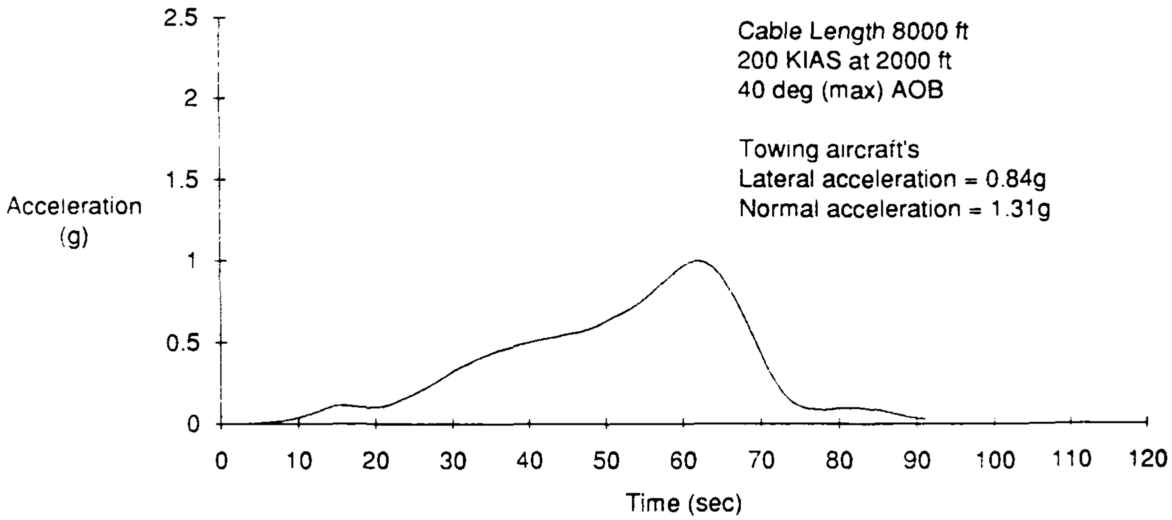
HAYES TPT-5A Flight Case 143
Target Absolute Acceleration



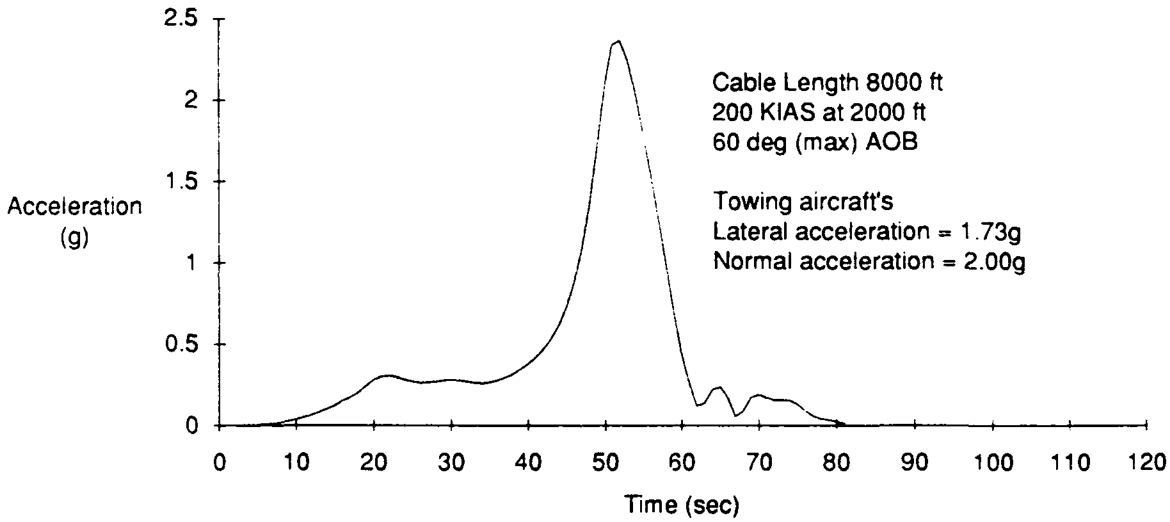
HAYES TPT-5A Flight Case 152
Target absolute acceleration



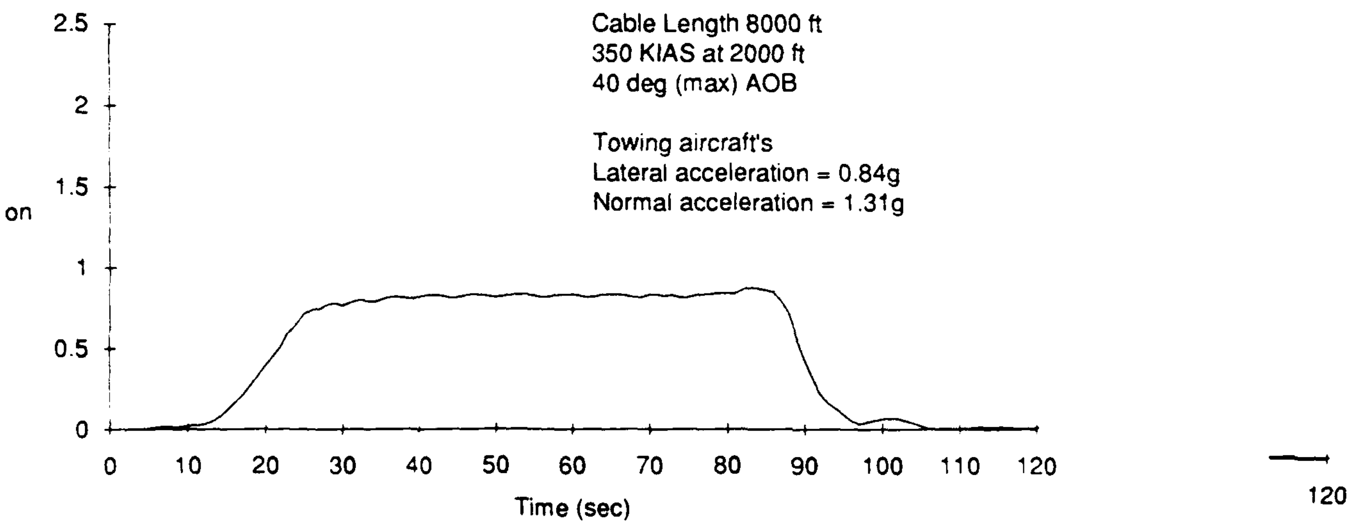
HAYES TPT-5A   Flight Case 311
Target Absolute Acceleration



HAYES TPT-5A Flight Case 313
Target Absolute Acceleration



HAYES TPT-5A Flight Case 341
Target Absolute acceleration



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The UK sourced CBAS computer model, with some enhancements implemented by the Aeronautical Research Laboratory, is being used to investigate the potential for Jindivik induced manoeuvres to provide transient response of the Hayes TPT-5A target to improve presentation realism for AAM exercises, both from a hardware and human operator point of view. This Memorandum examines the Jindivik performing a constant-altitude semi-circular banked turn, for different tow cable length/airspeed/angle-of-bank combinations and predicts target trajectories, accelerations, and tow cable tensions. However, as the model is unvalidated the results must be treated with caution.

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